FORM PTO-1390 (REV 5-93)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY DOCKET NO. P107242-00005
	TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	DATE: August 15, 2000
		U.S. APPLN. NO. (IF KNOWN, SEE 37 CFR 1.5) 09/600888

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP99/06533	November 24, 1999	December 28, 1998

TITLE OF INVENTION: LIGHT EMITTING DIODE AND FABRICATION PROCESS THEREFOR

APPLICANT(S) FOR DO/EO/US: Kingo SUZUKI; Hitoshi IKEDA

1. XX This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
   (THE BASIC FILING FEE IS ATTACHED)

2. __ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. XX This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT articles 22 and 39(1).

4. __ A proper demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. XX A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. __ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. XX has been transmitted by the International Bureau.
   c. __ is not required, as the application was filed in the United States Receiving Office (RO/US)

6. XX A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. __ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. __ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. __ have been transmitted by the International Bureau.
   c. __ have not been made; however, the time limit for making such amendments has NOT expired.
   d. __ have not been made and will not be made.

8. __ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. XX An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. __ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. XX An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. XX An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. XX A FIRST preliminary amendment.
    __ A SECOND or SUBSEQUENT preliminary amendment.

14. __ A substitute specification.

15. __ A change of power of attorney and/or address letter.

16. XX Other items or information:
    Check No. 298401
    Drawing(s) 5 sheets
    Notification of Change of Name and Address
    Request for Approval of Drawing Changes
    International Search Report
    Japanese Language Request Form
    Notification Concerning Submission of Priority Documents (PCT/IB/304)
    Notification of Receipt of Record Copy (PCT/IB/301)
    Notice Informing the Applicant of the Communication of the International Application to the Designated Offices (PCT/IB/308)
    International Publication No. WO00/41249

534 Rec'd PCT/PTO 15 AUG 2000

U.S. APPLN. NO. (IF KNOWN, SEE 37 C.F.R. 1.5) 09/600888	INTERNATIONAL APPLICATION NO. PCT/JP99/06533	ATTORNEY DOCKET NO. P107242-00005 DATE: August 15, 2000

17. XX The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5):

Search Report has been prepared by the EPO or JPO.....$840.00
International preliminary examination fee paid to USPTO (37 CFR 1.482)....$670.00
No international preliminary examination fee paid to USPTO (37 CFR1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))....$760.00
Neither international preliminary examination fee (37 CFR 1.482) or international search fee (37 CFR 1.445(a)(2)) paid to USPTO.....$970.00
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) .....$ 96.00

CALCULATIONS | PTO USE ONLY

ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 840.00	
Surcharge of $130.00 for furnishing the oath or declaration later than _ 20 _ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).					
Claims	Number Filed	Number Extra	Rate		
Total Claims	7 - 20 =	0	X $ 18.00		
Independent Claims	2 - 3 =	0	X $ 78.00		
Multiple dependent claim(s) (if applicable)			+ $260.00		
TOTAL OF ABOVE CALCULATIONS =				$ 840.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).					
SUBTOTAL =				$ 840.00	
Processing fee of $130.00 for furnishing the English translation later the _ 20 _ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +					
TOTAL NATIONAL FEE =				$ 840.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$ 880.00	
				Amount to be refunded	$
				Charged	$

a. XX A check in the amount of $ 880.00 to cover the above fees is enclosed.
b. __ Please charge my Deposit Account No. 01-2300 in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.
c. XX The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 01-2300.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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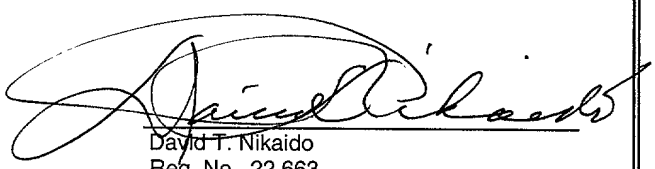


David T. Nikaido
Reg. No. 22,663

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

SUZUKI et al.

Serial No.: New Application — Group Art Unit:

Filed: August 15, 2000 — Examiner:

For: LIGHT EMITTING DIODE AND FABRICATION PROCESS THEREFOR

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

August 15, 2000

Sir:

Prior to calculation of the filing fee and prior to the examination of this application, please amend the above-identified application as follows:

IN THE CLAIMS:

Please cancel original claims 1 through 6.

Please add the following new claims.

--7. (Added) A light emitting diode comprising a pellet a major front surface of which is made of a GaAsP mixed crystal, characterized in that the major front surface is a rough surface.

8. (Added) A light emitting diode according to claim 7, characterized in that side surfaces of the pellet are rough surfaces.

9. (Added) A light emitting diode according to claim 7, characterized in that the rough surface is formed with fine projections having a diameter in a range of from 0.3 μm to 3 μm.

10. (Added) A light emitting diode according to claim 8, characterized in that the rough surface is formed with fine projections having a diameter in a range of from 0.3 μm to 3 μm.

11. (Added) A fabrication process for a light emitting diode having a pellet a major front surface of which is made of a GaAsP mixed crystal, characterized in that the pellet is treated with an etching solution of an aqueous solution containing Br_2 or I_2 to form fine projections on at least the major front surface of the pellet.

12. (Added) A fabrication process for a light emitting diode according to claim 11, characterized in that the etching solution is an aqueous solution further containing nitric acid, hydrofluoric acid and acetic acid.

13. (Added) A fabrication process for a light emitting diode according to claim 12, characterized in that the etching solution contains 40 to 80 parts of nitric acid, 40 to 300 parts of hydrofluoric acid and 400 to 2000 parts of acetic acid based on 1 part of Br_2 or I_2 in a molar ratio. --

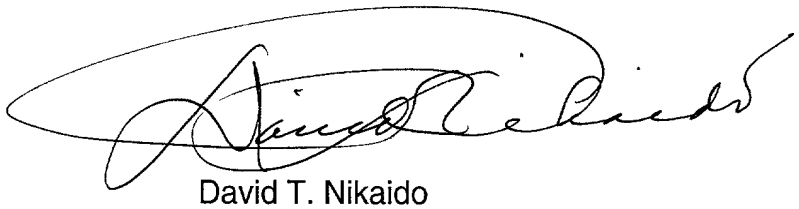
REMARKS

The above amendments to the claims have been made to correct the multiple dependency of the claims and to put the application in better condition for examination. No new matter has been added.

In the event that any fees are due in connection with this paper, please charge our Deposit Account No. 01-2300.

Respectfully submitted,

ARENT FOX KINTNER PLOTKIN & KAHN, PLLC



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DESCRIPTION

LIGHT EMITTING DIODE AND FABRICATION PROCESS THEREFOR

Technical Field

The present invention relates to a light emitting diode [hereinafter may be simply referred to as LED (an abbreviation of Light Emitting Diode)] and a fabrication process therefor, and more particularly, to a light emitting diode made of a gallium arsenide phosphide $GaAs_{1-x}P_x$ mixed crystal (hereinafter the light emitting diode and $GaAs_{1-x}P_x$ may be simply referred to as GaAsP LED and GaAsP, respectively) and a fabrication process therefor.

Background Art

A light emitting diode made of a gallium arsenide phosphide $GaAs_{1-x}P_x$ mixed crystal can emit yellow light with a wavelength of 583 nm (x = 0.90), orange light with a wavelength of 626 nm (x = 0.65), red light with a wavelength of 648 nm (x = 0.50) or the like by changing a bandgap width through varying a mixed crystal ratio (x) and has been employed as a light source for a display device and so on.

In general, an LED is required to have high luminous intensity. A light emission efficiency of the LED is determined by an internal quantum efficiency and a light extraction efficiency. Since the internal quantum efficiency is determined by composition of materials of which the LED is made, in order to increase the light emission efficiency, the light extraction efficiency is necessarily increased by suppressing a loss due to optical absorption in the

interior of the LED and a loss of light that cannot be extracted to the outside by total reflection at an interface between a light emitting surface and the air.

In order to increase the light extraction efficiency, there have been known processes in which a semiconductor wafer having a p-n junction is cut into pellets in a discrete state and surfaces of the pellets are roughened (Japanese Patent Laid-open Publication Nos. 4-354382 and 6-151959 and others). It is assumed that when the pellet surfaces are roughened, since a probability of total reflection of emitted light at an interface between the light emitting surface and the air decreases, the light extraction efficiency may be increased.

Surface roughening of a pellet can be simply effected by wet etching. For example, in case of a gallium phosphide GaP pellet, surfaces of the pellet can be roughened by etching them with an aqueous solution of hydrochloric acid, that is, HCl (Japanese Patent Laid-open Publication No. 4-354382). Further, in case of surface roughening of an AlGaAs mixed crystal, hydrofluoric acid (Japanese Patent Laid-open Publication No. 6-151959) and a mixed solution of nitric acid : sulfuric acid = 95 : 5 (Japanese Patent Laid-open Publicaton No. 10-200156) are effective.

In case of a gallium arsenide phosphide GaAsP mixed crystal, however, there has been no success in developing an etching solution suitable for roughening a major front surface of a pellet thereof and as shown in FIG. 6 the major front surface 46 of the pellet 40 of a GaAsP mixed crystal remains in a mirror state.

The pellet 40 of a GaAsP mixed crystal is produced by for example a process wherein an n-type GaP epitaxial layer 42, an n-type $GaAs_{1-x}P_x$ mixed

crystal ratio variable layer 43 in which the mixed crystal ratio varies, a nitrogen doped n-type $GaAs_{1-x}P_x$ mixed crystal ratio constant layers 44 and 45 are sequentially deposited on an n-type GaP single crystal substrate 41; thereafter, zinc Zn is diffused through the surface of the $GaAs_{1-x}P_x$ mixed crystal ratio constant layer 45 to invert a conductivity thereof to p-type and form a p-n junction at the boundary between the mixed crystal ratio constant layers 44 and 45; subsequently, gold alloy is vacuum evaporated on the major front and rear surfaces 46 and 47 to form a p-side electrode 51 and an n-side electrode 52, respectively; and finally the resultant product is cut in the form of chips by dicing.

In FIG. 6, reference numerals 48a and 48b indicate side surfaces of the pellet which are formed as cut faces almost normal to the major front surface 46 when the pellet is fabricated in the form of chips by dicing. The pellet has further two side surfaces in addition to the side surfaces 48a and 48b shown in FIG. 6.

The present inventors have conducted serious studies in order to develop an etching solution for roughening of at least a major front surface of a GaAsP mixed crystal and as a result, made a finding that an aqueous solution including bromine Br_2 or iodine I_2 is preferable as the etching solution. The present invention has been completed through various experiments using such an etching solution.

It is an object of the present invention to provide a light emitting diode (GaAsP LED) made of a gallium arsenide phosphide GaAsP mixed crystal which has luminous intensity greatly improved as compared with a conventional one, and a fabrication process therefor.

Disclosure of the Invention

In order to solve the above problem, according to the present invention, there is provided a light emitting diode comprising a pellet a major front surface of which is made of a GaAsP mixed crystal, characterized in that the major front surface is a rough surface.

In the case where side surfaces of the pellet are rough surfaces, a higher light extraction efficiency can be achieved. The rough surface is preferably formed with fine projections having a diameter in a range of from 0.3 μm to 3 μm.

A fabrication process for a light emitting diode having a pellet a major front surface of which is made of a GaAsP mixed crystal according to the present invention is characterized in that the pellet is treated with an etching solution of an aqueous solution containing Br_2 or I_2 to form fine projections on at least the major front surface of the pellet.

The etching solution is preferably an aqueous solution further containing nitric acid, hydrofluoric acid and acetic acid in addition to Br_2 or I_2. The etching solution preferably contains 40 to 80 parts of nitric acid, 40 to 300 parts of hydrofluoric acid and 400 to 2000 parts of acetic acid based on 1 part of Br_2 or I_2 in a molar ratio.

Brief Description of the Drawings

FIG. 1 is a schematic sectional view showing a major front surface and side surfaces of a pellet for a light emitting diode of the preset invention.

FIG. 2 is a view illustrating angles of light beams getting to a light emitting surface, and light transmission and reflection states, where FIG.

2(A) shows the light transmission state and FIG. 2(B) shows the light reflection state, respectively.

FIG. 3 is a view illustrating angles of light beams getting to a light emitting surface with fine projections, and light transmission and reflection states, wherein FIG. 3(A) shows a case where a diameter of the projection is in a range of from 0.3 μm to 3 μm, FIG. 3(B) shows a case where a diameter of the projection is more than 3 μm and FIG. 3(C) shows a case where a diameter of the projection is less than 0.3 μm.

FIG. 4 is a flow chart showing procedures of a fabrication process for a light emitting diode of the present invention.

FIG. 5 is a view showing an embodiment of a light emitting diode.

FIG. 6 is a schematic sectional view showing a major front surface and side surfaces of a pellet for a conventional light emitting diode.

Best Mode for Carrying out the Invention

Detailed description will be given of a light emitting diode according to the present invention and of a fabrication process therefor below with reference to the accompanying drawings. It should be understood that embodiments are exemplarily shown and various modifications and alterations may be carried out without departing from the technical idea of the present invention.

FIG. 1 is a schematic sectional view showing a pellet 20 of a light emitting diode made of gallium arsenide phosphide of the present invention, which may be referred to as GaAsP pellet.

A major front surface 6 made of a GaAsP mixed crystal, as shown in

FIG. 1, is changed to a rough surface with fine projections by wet etching in order to improve a light extraction efficiency, and the etching conditions are adjusted so that a diameter of the projection of the rough surface is in a range of from 0.3 μm to 3 μm.

Light emitted from the gallium arsenide phosphide GaAsP mixed crystal has wavelengths of around 600 nm ranging from about 580 nm of yellow to about 650 nm of red at a peak wavelength. When the fine projections of the major front surface 6 of the pellet 20 is adjusted so as to be in a range of from 0.3 μm to 3 μm, a probability of total reflection of light decreases satisfactorily, thereby improving a light extraction efficiency.

More detailed description will be given of a light extraction efficiency. As described above, in order to obtain a high luminous intensity, it is necessary that the light extraction efficiency is improved by reducing a ratio of emitted light being not extracted to the outside due to total reflection at an interface between the light emitting surface and the air.

Since at a wavelength in the vicinity of 600 nm, the refractive index (n) of GaP is about 3.3 and the refractive index (n) of GaAs is about 3.8, the refractive index (n) of GaAsP, which is a mixed crystal thereof, is in a range of from about 3.3 to about 3.8. In the case where a light beam is transmitted into the air of a refractive index = 1 from a medium having such a high refractive index (n), a critical angle of total reflection θ is expressed by the following equation:

$\theta = \sin^{-1}(1/n)$

Accordingly, in a case of GaAsP having a refractive index (n) = about 3.3 to about 3.8, there is given a critical angle of total reflection θ = about 15° to

about 18° .

That is, when a light emitting surface is a plane surface as shown in FIG. 2, there is emitted into the air only light getting to the interface at an angle nearly normal thereto and less than the critical angle of total reflection θ 〔FIG. 2(A)〕 , while light getting to the interface at an angle larger than the critical angle of total reflection θ is totally reflected into the interior of the crystal and eventually absorbed therein 〔FIG. 2(B)〕 .

Therefore, the interface between the light emitting surface and the air is changed to a rough surface by wet etching so as to form fine projections, but not a plane surface. When fine projections are formed on the interface, as shown in FIG. 3(A), there exist locally convex surfaces smaller than the critical angle of total reflection θ, so light getting to the interface at an angle larger than the critical angle of total reflection θ can transmit into the air through the convex surfaces 〔FIG. 3(A)〕 .

In case of a GaAsP mixed crystal, the fine projections may preferably have a diameter in a range of from 0.3 μm to 3 μm 〔FIG. 3(A)〕 . If the diameter thereof is larger than 3 μm, the projection surface to the light wavelength is so gentle as to locally work as a mirror surface 〔FIG. 3(B)〕. To the contrary, if the diameter thereof is smaller than 0.3 μm, the projection level to the light wavelength is so small as to become substantially a mirror surface 〔FIG. 3(C)〕 . The term "a diameter of a fine projection" used in the present invention means a length from the foot of a projection to the foot of the next projection as shown in FIG. 3. While, in FIG 3, fine projections on the interface are drawn as a series of semi-spherical projections, it may be sufficient for projections of arc-like sectional shapes to be formed densely.

In FIG. 1, when there are formed rough surfaces having fine projections in a range of from 0.3 μm to 3 μm on not only the major front surface 6 but side surfaces 8 of the pellet (8a, 8b and other two sides being further included, not shown in FIG. 1), a light extraction efficiency is further improved.

Then, description will be given of a fabrication process for a light emitting diode according to the present invention using FIG. 4.

First, an n-type GaP epitaxial layer 2, an n-type $GaAs_{1-x}P_x$ mixed crystal ratio variable layer 3, in which the mixed crystal ratio varies, a nitrogen doped n-type $GaAs_{1-x}P_x$ mixed crystal ratio constant layers 4 and 5 are sequentially deposited on an n-type GaP single crystal substrate 1 a major front surface of which has a (100) orientation, and thereafter, zinc Zn is diffused through the surface of the $GaAs_{1-x}P_x$ mixed crystal ratio constant layer 5 to invert a conductivity thereof to p-type and obtain a GaAsP epitaxial wafer 10 with a p-n junction at the boundary between the mixed crystal ratio constant layers 4 and 5 〔step (A)〕.

Subsequently, gold alloy is vacuum evaporated on the major front and rear surfaces 6 and 7 to form a p-side electrode 11 and an n-side electrode 12, respectively 〔step (B)〕. Then, the GaAsP epitaxial wafer 10 is put on a adhesive tape 13 so as to cover the n-side electrode 12 and the GaAsP epitaxial wafer 10 is cut into pellets 20 each of 0.3 mm × 0.3 mm square by dicing 〔step (C)〕.

Further, the cut pellet 20 is subjected to etching by the use of a first etching solution composed of 96 % sulfuric acid H_2SO_4 : 32 % hydrogen peroxide H_2O_2 : water H_2O = 3 : 1 : 1 in a volume ratio for 2 minutes to remove

mechanical damage induced by dicing [step (D)] .

Furthermore, the pellet 20 is subjected to a second etching solution of an aqueous solution containing bromine Br_2 or iodine I_2 in order to form fine projections in a range of from 0.3 μm to 3 μm on the major front surface 6 and the side surfaces 8a and 8b of the pellet 20 [step (F)] . The aqueous solution containing Br_2 or I_2 has not been employed conventionally for surface roughening treatment of a GaAsP mixed crystal. In this etching, the major rear surface 7 of the pellet 20 is covered with the adhesive tape 13 to protect the surface from the second etching solution so as not to be roughened. A major rear surface 7 preferably has a mirror surface rather than a rough surface because of increase in a light extraction efficiency due to the fact that light can not escape through the major rear surface 7.

Describing in a more concrete manner, the second etching solution of an aqueous solution containing in addition to Br_2 or I_2, 40 to 80 parts of nitric acid HNO_3, 40 to 300 parts of hydrofluoric acid HF and 400 to 2000 parts of acetic acid CH_3COOH based on 1 part of Br_2 or I_2 in a molar ratio is prepared and thereafter, the major front surface 6, side surfaces 8a and 8b and so on of the GaAsP pellet 20 are treated with the second etching solution for a predetermined time to form rough surfaces having fine projections in a range of from 0.3 μm to 3 μm. An optimum etching time varies to some extent according to a mixed crystal ratio of GaAsP and composition of the etching solution. Since the second etching solution roughens not only a GaAsP mixed crystal but GaP partly exposed on the side surfaces of the pellet 20 as well, all of the major front surface 6, side surfaces 8a and 8b and so on exposed to the second etching solution are changed to rough surfaces.

Description will be given, taking up further concrete examples, of conditions of etching according to the present invention and luminous intensity of a light emitting diode whose pellet is made of a GaAsP mixed crystal having fine surface projections formed by the etching. The following examples are shown for exemplary purposes and as a matter of course should not be construed as restrictive.

(Example 1)

A GaAsP pellet 20 a major front surface of which has a (100) orientation was etched with a first etching solution composed of 96 % sulfuric acid H_2SO_4: 32 % hydrogen peroxide H_2O_2 : water H_2O = 3 : 1 : 1 in a volume ratio for 2 minutes 〔FIG. 4(D)〕 to remove mechanical damage induced by dicing and further etched with a second etching solution of an aqueous solution containing 60 parts of nitric acid, 200 parts of hydrofluoric acid and 800 parts of acetic acid based on 1 part of I_2 in a molar ratio at 30°C for 75 seconds to form fine projections in a range of from 0.3 μm to 3 μm on the major front surface 6, side surfaces 8a and 8b and so on of the GaAsP pellet 20 〔FIG. 4(F)〕 .

Successively, as shown in FIG. 5, the GaAsP pellet 20 was fixed on a stem 34 with silver paste 36 and after wire bonding with gold fine wires 32, molded using transparent epoxy resin 38 to fabricate a light emitting diode 30.

Then, there was measured luminous intensity of yellow light with a wavelength of 580 nm by applying a DC current of 20 mA to the fabricated light emitting diode 30 〔FIG. 4(G)〕 . Measurement results of the luminous intensity are shown in Table 1 (A). In comparison with Comparative

Example 1 shown next, the luminous intensity is improved by 88 %. The improvement of the luminous intensity means that the light extraction efficiency was improved by roughening of surfaces of the pellet 20.

(Comparative Example 1)

A light emitting diode 30 was fabricated in the same way as Example 1 with the exception that there was not performed etching to form fine projections on the major front surface 6 and side surfaces 8a and 8b of a GaAsP pellet 20. There was measured luminous intensity by applying a DC current of 20 mA to the fabricated light emitting diode 30 and results thereof are shown in Table 1(B).

(Example 2)

A light emitting diode 30 emitting yellow light with a wavelength of 586 nm was fabricated in the way similar to Example 1 and luminous intensity thereof was measured〔Table 1(C)〕. In comparison with Comparative Example 2 shown next, the luminous intensity was improved by 73 %.

(Comparative Example 2)

A light emitting diode 30 was fabricated in the same way as Example 2 with the exception that there was not performed etching to form fine projections on the major front surface 6, side surfaces 8a and 8b and so on of a GaAsP pellet 20. There was measured luminous intensity by applying a DC current of 20 mA to the fabricated light emitting diode 30 and results thereof are shown in Table 1(D).

(Example 3)

A light emitting diode 30 emitting yellow-brown light with a

wavelength of 605 nm was fabricated in the way similar to Example 1 and luminous intensity thereof was measured 〔Table 1(E)〕. In comparison with Comparative Example 3 shown next, the luminous intensity was improved by 73 %.

(Comparative Example 3)

A light emitting diode 30 was fabricated in the same way as Example 3 with the exception that there was not performed etching to form fine projections on the major front surface 6, side surfaces 8a and 8b and so on of a GaAsP pellet 20. There was measured luminous intensity by applying a DC current of 20 mA to the fabricated light emitting diode 30 and results thereof are shown in Table 1(F).

(Example 4)

A light emitting diode 30 emitting orange light with a wavelength of 630 nm was fabricated in the way similar to Example 1 and luminous intensity thereof was measured 〔Table 1(G)〕. In comparison with Comparative Example 4 shown next, the luminous intensity was improved by 51 %.

(Comparative Example 4)

A light emitting diode 30 was fabricated in the same way as Example 4 with the exception that there was not performed etching to form fine projections on the major front surface 6, side surfaces 8a and 8b and so on of a GaAsP pellet 20. There was measured luminous intensity by applying a DC current of 20 mA to the fabricated light emitting diode 30 and results thereof are shown in Table 1(H).

Table 1

		Emission Wavelength (nm)	Emission Color	Luminous Intensity (mcd)	Improvement of Luminous Intensity (%)
(A)	Example 1	580	yellow	5.41	88
(B)	Comp. Example 1	580	yellow	2.88	
(C)	Example 2	586	yellow	6.68	73
(D)	Comp. Example 2	586	yellow	3.86	
(E)	Example 3	605	yellow-brown	4.36	73
(F)	Comp. Example 3	605	yellow-brown	2.52	
(G)	Example 4	630	orange	4.55	51
(H)	Comp. Example 4	630	orange	3.01	

While iodine I_2 was employed for preparation of the second etching solutions in the present Examples, similar results can be obtained when bromine Br_2 is employed in the same composition as in the case of iodine I_2.

Furthermore, while light emitting diodes emitting yellow, yellow-brown and orange light are described in the present Examples, similar results can be obtained for a light emitting diode emitting red light. Besides, since in the present Examples the surface roughening treatment was applied after formation of the p-side electrodes 11 on the major front surfaces 6, the surfaces under the p-side electrodes 11 were not changed to rough surfaces, but the entire major front surfaces 6 can naturally be roughened when the surface roughening treatment is applied prior to formation of the p-side electrodes.

Capability of Exploitation in Industry

As described above, according to the present invention, a light extraction efficiency can be improved by forming fine projections on surfaces of a GaAsP pellet through roughening the surfaces and as a result, luminous intensity can be improved by about 50 % to about 90 % as compared with a conventional one. Further, surface roughening of a major front surface of a GaAsP pellet can be achieved by employing an etching solution of an aqueous solution containing Br_2 or I_2. To be more concrete, fine projections on the major front surface and side surfaces of the GaAsP pellet 20 can be formed by performing surface roughening treatment with an etching solution of an aqueous solution further containing nitric acid, hydrofluoric acid and acetic acid in addition to Br_2 or I_2.

CLAIMS

1. A light emitting diode comprising a pellet a major front surface of which is made of a GaAsP mixed crystal, characterized in that the major front surface is a rough surface.

2. A light emitting diode according to claim 1, characterized in that side surfaces of the pellet are rough surfaces.

3. A light emitting diode according to claim 1 or 2, characterized in that the rough surface is formed with fine projections having a diameter in a range of from 0.3 μm to 3 μm.

4. A fabrication process for a light emitting diode having a pellet a major front surface of which is made of a GaAsP mixed crystal, characterized in that the pellet is treated with an etching solution of an aqueous solution containing Br_2 or I_2 to form fine projections on at least the major front surface of the pellet.

5. A fabrication process for a light emitting diode according to claim 4, characterized in that the etching solution is an aqueous solution further containing nitric acid, hydrofluoric acid and acetic acid.

6. A fabrication process for a light emitting diode according to claim 5, characterized in that the etching solution contains 40 to 80 parts of nitric acid, 40 to 300 parts of hydrofluoric acid and 400 to 2000 parts of acetic acid based on 1 part of Br_2 or I_2 in a molar ratio.

ABSTRACT

Provided are a light emitting diode (GaAsP LED) made of a gallium arsenide phosphide GaAsP mixed crystal whose luminous intensity is greatly improved as compared with a conventional one, and a fabrication process therefor. In a light emitting diode comprising a pellet a major front surface of which is made of a GaAsP mixed crystal, the major front surface is a rough surface.

FIG. 1

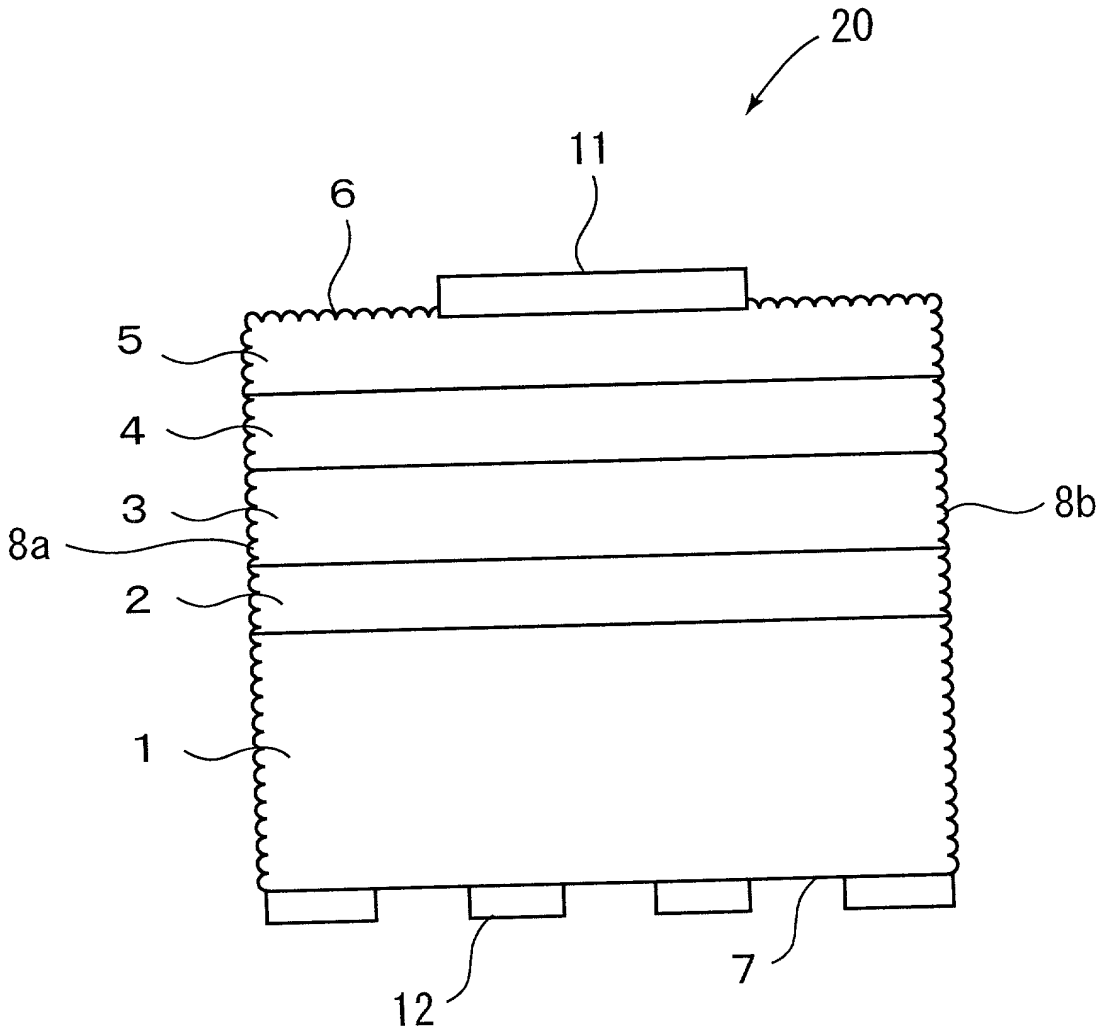


FIG. 2

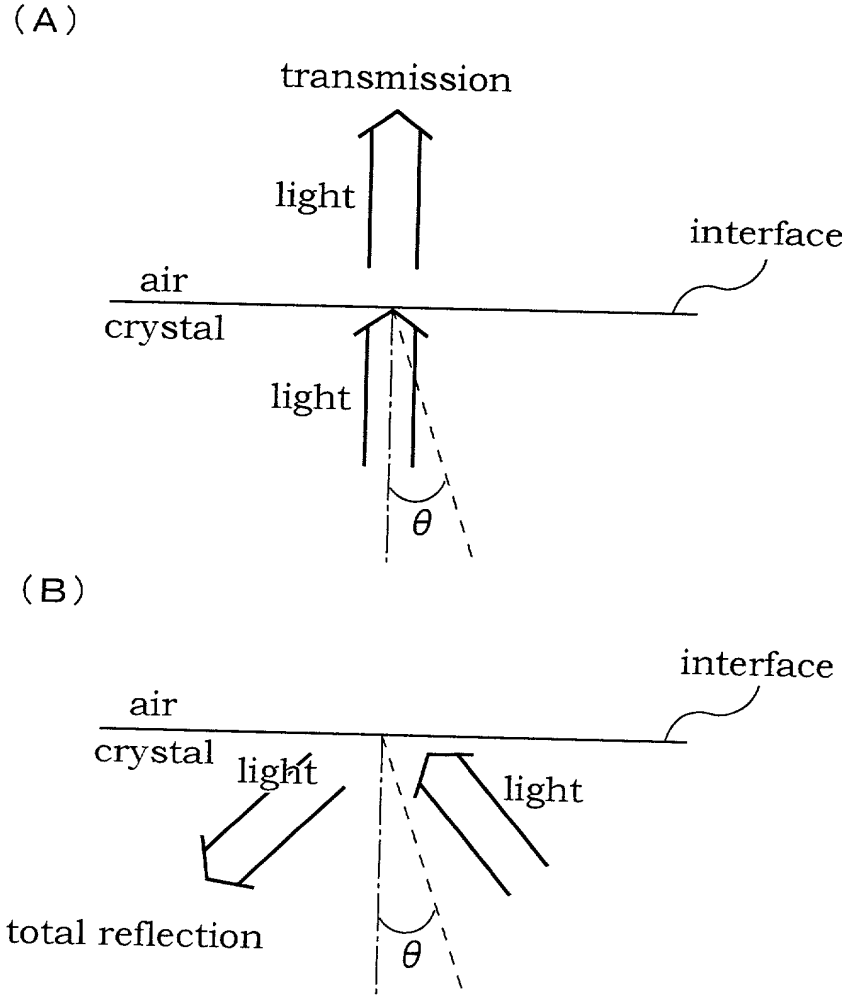

(A)
transmission
light
interface
air
crystal
light
θ
(B)
interface
air
crystal
light
light
total reflection
θ

FIG. 3

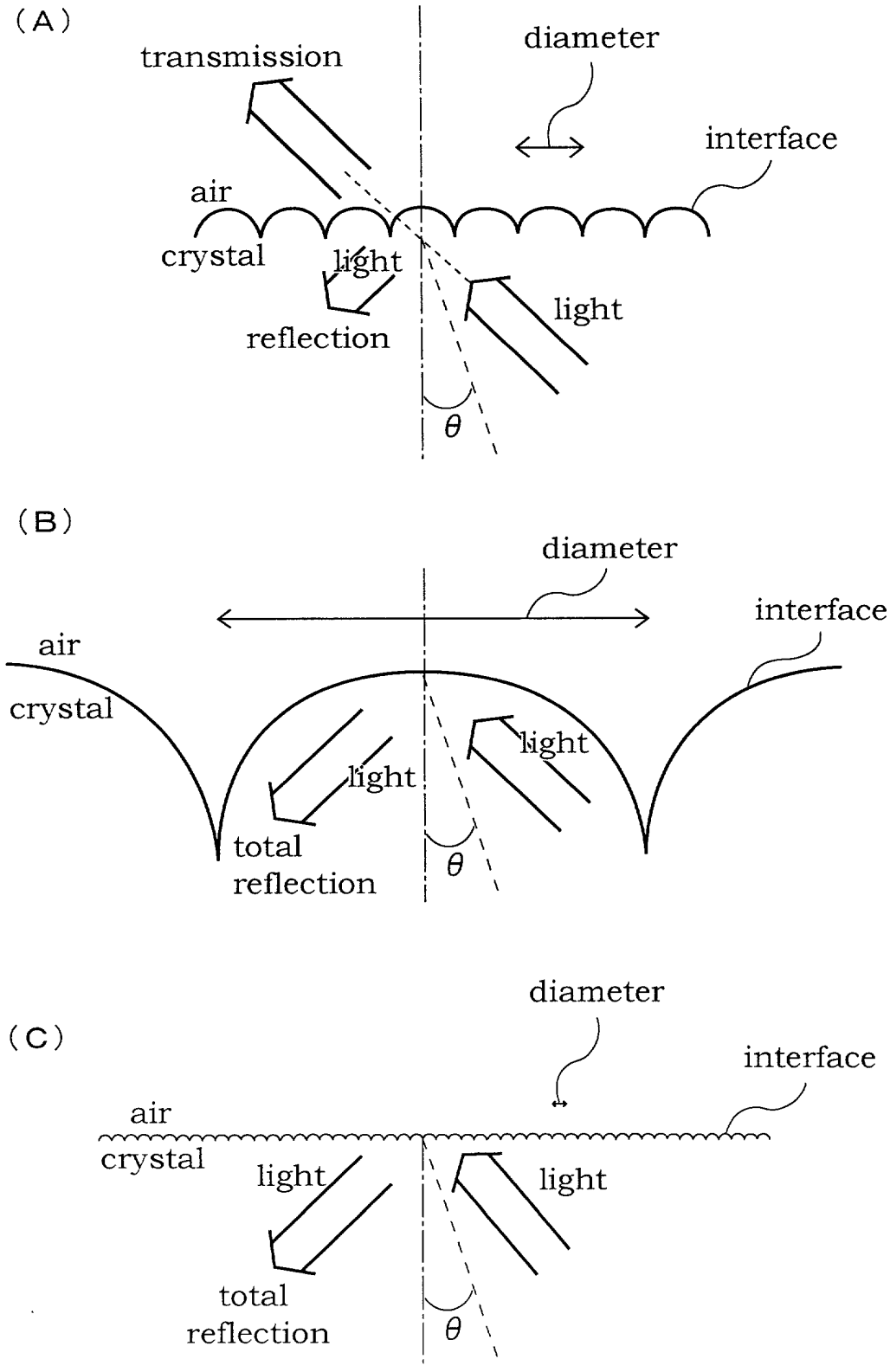

(A)
transmission
diameter
interface
air
crystal
light
reflection
light
θ
(B)
diameter
interface
air
crystal
light
light
total
reflection
θ
(C)
diameter
interface
air
crystal
light
light
total
reflection
θ

FIG. 4

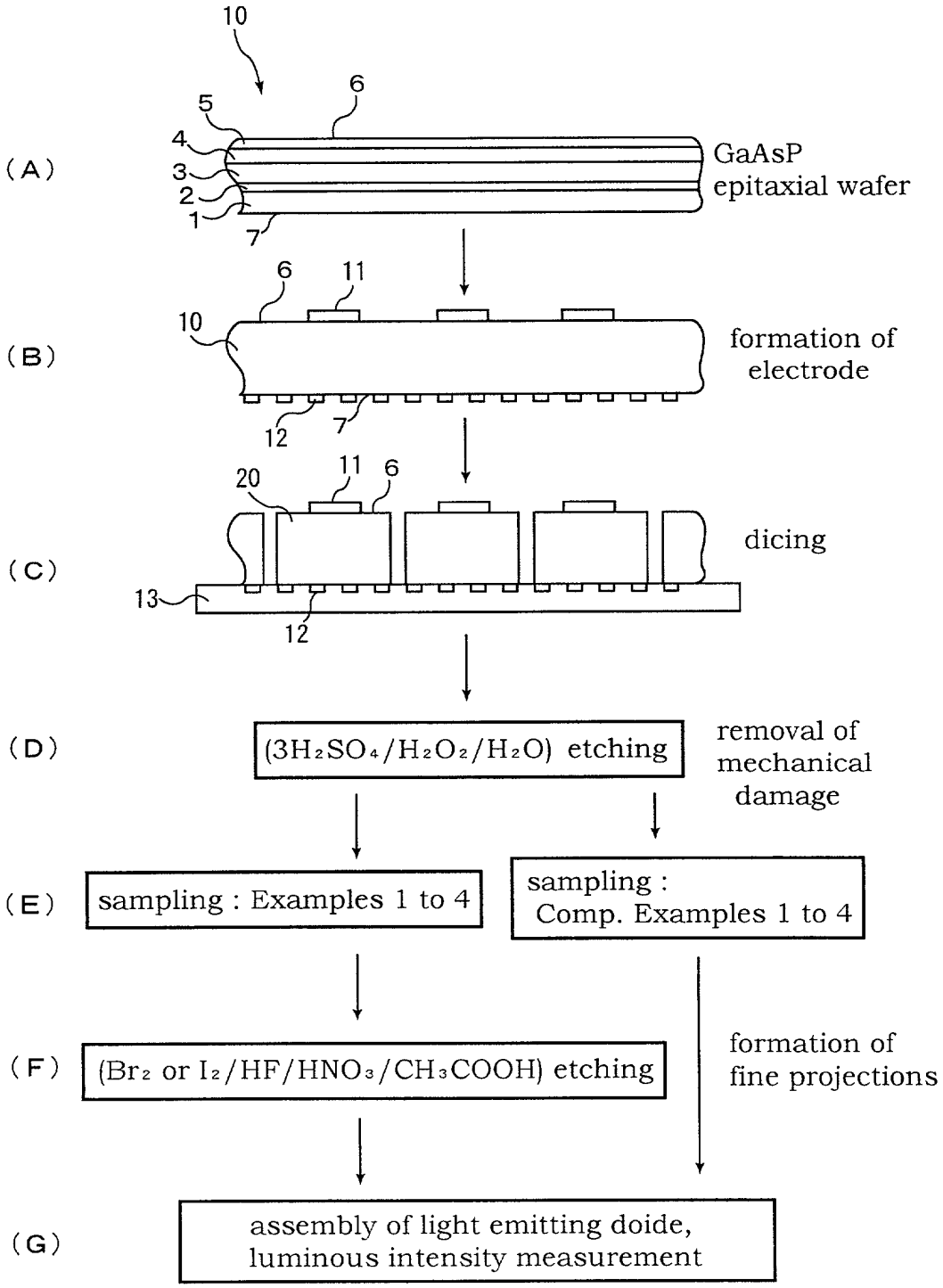

10
6
5
4
3
2
1
7
(A)
GaAsP
epitaxial wafer
6
11
10
(B)
formation of
electrode
12
7
20
11
6
(C)
dicing
13
12
(D)
(3H2SO4/H2O2/H2O) etching
removal of
mechanical
damage
(E)
sampling : Examples 1 to 4
sampling :
Comp. Examples 1 to 4
(F)
(Br2 or I2/HF/HNO3/CH3COOH) etching
formation of
fine projections
(G)
assembly of light emitting doide,
luminous intensity measurement

FIG. 5

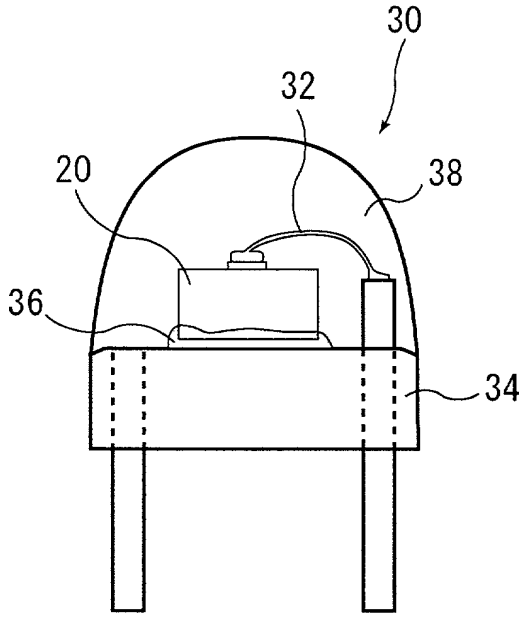
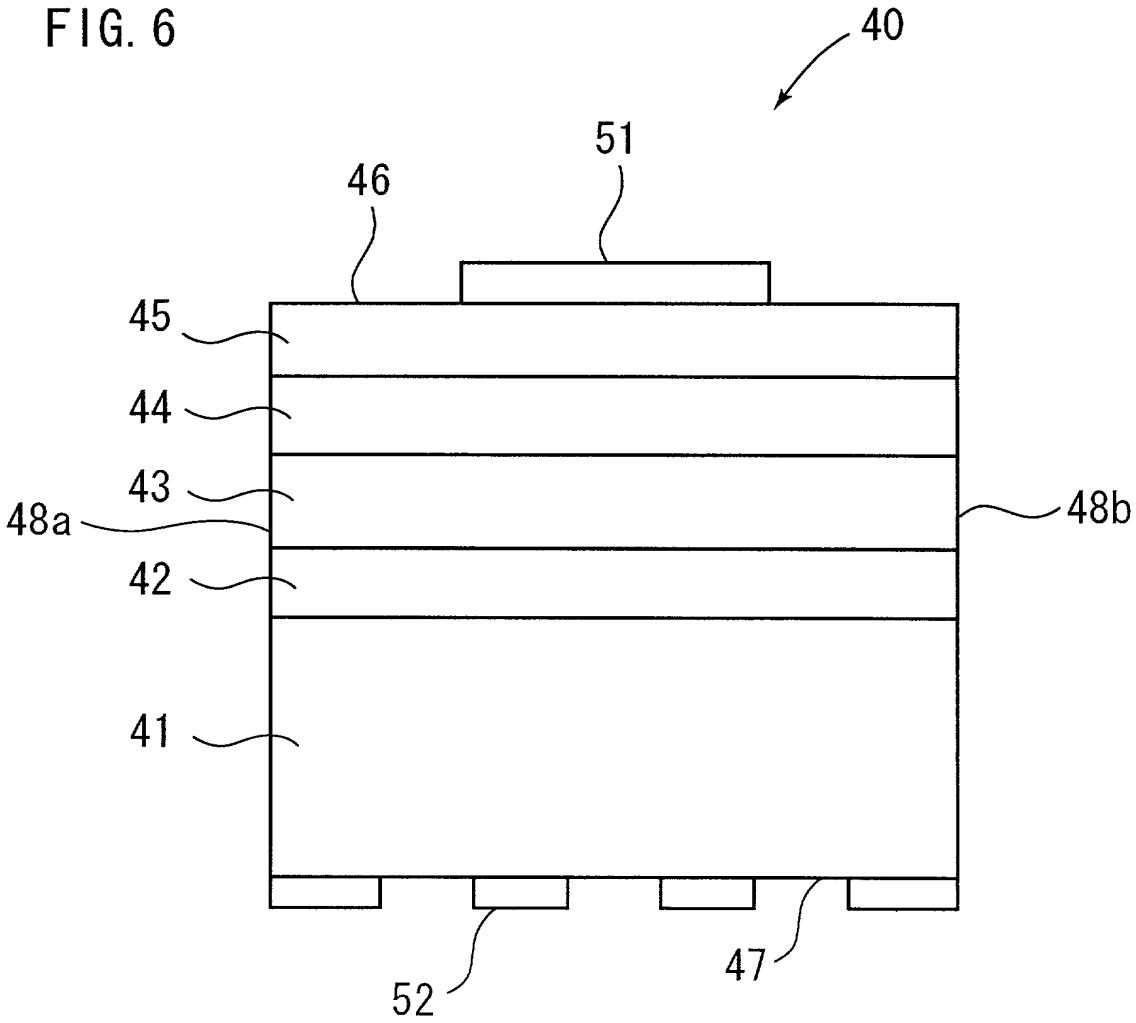


FIG. 6



PTO/SB/106 (8-96)
Approved for use through 9/30/98. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

☐ 下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

LIGHT EMITTING DIODE AND FABRICATION PROCESS THEREFOR

上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ __月__日に提出され、米国出願番号または特許協定条約国際出願番号を_____とし、
（該当する場合）_____ に訂正されました。

☒ was filed on November 24, 1999
as United States Application Number or
PCT International Application Number PCT/JP99/06533
and was amended on
_____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編第１条５６項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

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私は、米国法典第３５編１１９条(a)-(d)項又は３６５条(b)項に基き下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約３６５(a)項に基ずく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Not Claimed 優先権主張なし
10-373153	JAPAN	28/12/1998	☐
			☐

私は、第３５編米国法典１１９条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)

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I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

私は、私自身の知識に基ずいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基ずく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第１８編第１００１条に基ずき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration
(日本語宣言書)

委任状： 私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。（弁護士、または代理人の氏名及び登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith *(list name and registration number)*

書類送付先

(13)

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（第三以降の共同発明者についても同様に記載し、署名をすること）

(Supply similar information and signature for third and subsequent joint inventors.)

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国籍		Citizenship	
私書箱		Post Office Address	
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第四共同発明者の署名	日付	Fourth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
第五共同発明者名		Full name of fifth joint inventor, if any	
第五共同発明者の署名	日付	Fifth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
第六共同発明者名		Full name of sixth joint inventor, if any	
第六共同発明者の署名	日付	Sixth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	

第七共同発明者名		Full name of seventh joint inventor, if any	
第七共同発明者の署名	日付	Seventh inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
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第八共同発明者の署名	日付	Eighth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
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第九共同発明者名		Full name of ninth joint inventor, if any	
第九共同発明者の署名	日付	Ninth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
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住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

SUZUKI et al.

Serial No.: New Application

Group Art Unit:

Filed: August 15, 2000

Examiner:

For: LIGHT EMITTING DIODE AND FABRICATION PROCESS THEREFOR

NOTIFICATION OF CHANGE OF NAME AND ADDRESS

Commissioner for Patents
Washington, D.C. 20231

August 15, 2000

Sir:

Kindly change the correspondence name and address for the above-identified application to the following:

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Should any fees be due with respect to this paper, please charge Counsel's Deposit Account No. 01-2300.

Respectfully submitted,

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